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JACK PINE BUDWORM SURVEYS

By

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INTRODUCTION

The jack pine budworm, Choristoneura pinus Freeman, is the most important native defoliator of jack pine, Pinus banksiana Lambert, in the Great Lakes region. Outbreaks occur periodically and persist for one to three years. Defoliation, reported somewhere almost every year, may cause considerable mortality and top killing in merchandise trees and understory seedlings and saplings. Defoliation also reduces growth and production of pollen and seeds. Jack Pine is an important pulpwood species, and if it is to be grown successfully, methods for sampling budworm populations and predicting fluctuations must be made available to land managers and survey entomologists.

The objective of this manual is to describe survey methods presently available for determining population levels of the jack pine budworm, and to present methods for evaluating and/or predicting the damage such populations may cause. The manual begins with a brief review of the taxonomy and life history of the budworm, then discusses briefly some of the sampling methods and sampling units that have been used historically to evaluate budworm abundance. The section on surveys discusses in detail the two major systems being used to evaluate population trends: 1) the Wisconsin system, and 2) Cluster Sampling. There is a short section on Control Decision surveys. The section on Damage Appraisals discusses aerial and ground surveys to evaluate defoliation and an impact survey to estimate losses due to defoliation. A section on Emergency Control Evaluations discusses methods for evaluating chemical control operations. The manual concludes with a brief review of some methods for the rapid processing of samples.

TAXONOMY AND LIVE HISTORY

The jack pine budworm and the spruce budworm, Choristoneura fumiferana (Clem), are almost identical taxonomically. In 1953 Freeman described the jack pine form as a new species, naming it Choristoneura pinus. Subsequently, Freeman (1967) gave the jack pine budworm new status as the subspecies Choristoneura pinus pinus to distinguish it from the subspecies Choristoneura pinus maritima (Freeman), which feeds on Virginia pine, Pinus virginiana Mill., and pitch pine, Pinus rigida Mill.

Depending on the locality and weather conditions, the adults emerge from late June to early August. Males emerge first and are active fliers. Gravid females are relatively inactive, but spent females fly actively. The females lay eggs on old-growth needles throughout the crowns of mature trees. The egg masses contain approximately 50 eggs, but numbers are quite variable. Each mass usually consists of two or three rows of eggs which overlap one another like fish scales.

The eggs hatch in 7 to 10 days from late June to early August, again depending on weather conditions and locality. The first instar larvae wander for a few days then spin silken cases (hibernacula) in sheltered places such as under bark and cone scales. The larvae molt without feeding to the second instar within the hibernacula where they remain until the following spring. During the winter the larvae appear shriveled and lifeless within the hibernacula. In spring they absorb water and become plump and active. The larvae emerge from the hibernacula in May at about the time male cones open.

The newly emerged larvae enter male cones or feed on developing shoots. Ocassionally they mine buds or needles. The larvae spin a light web about themselves as they feed; they mature in about six weeks after passing through six or seven larval instars. About mid-June most larvae migrate from the male cones to feed on the current year's foliage; some remain in the male cones for the entire period. The larvae chew off needles at their bases on new foliage. The web of silk they feed under holds the needles on the twig. When these needles turn brown in June or July, the amount of

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browning can be used to estimate the severity of defoliation in jack pine stands. When population levels are high old growth needles may be eaten after the new growth has been consumed.

Larvae pupate from mid-June to late July. In about a week the adults emerge, mate, and lay eggs.

REVIEW OF SAMPLING METHODS AND UNITS

A number of methods have been employed to estimate jack pine budworm population levels, and to evaluate the damage such populations might cause. One of the earliest attempts to evaluate larval populations involved tree beating (Kulman and Hodson, 1962). The lower branches of open grown trees or trees at the edge of a stand were struck three times with a 10-foot pole. Larvae that fell onto a sheet spread below the tree were then counted. Lejeune and Black (1950) counted the number of larvae on the terminal buds of four branches (two branches were removed from the upper half and two from the lower half of the crown of each tree). Populations were expressed in terms of the number of larvae per 100 terminals.

Kulman and Hodson (1962) suggested that because the larvae feed principally on new growth, distal clusters of new shoots on prominent branches would make a good sampling unit. Fifteen-inch branch samples have been widely used in research and survey work (Dixon 1961; Benjamin 1965; Stewart 1977). Two branches are usually removed form the mid-crowns of the trees sampled.

Batzer and Jennings (1980) utilized the total length of foliated branch for estimating budworm populations in dense jack pine. Sample branches were taken from the upper and lower halves of the crown. Twigs were folded against the main branch and then total foliated length determined.

Foltz et al. (1968) developed a cluster sampling method for studying the population dynamics of the jack pine budworm. Their findings agreed with those of Kulman and Hodson. Populations are highest on the distal portions of branches, and diminish toward the trunk. They concluded that the distal 36 inches of branch constituted a better sampling unit than either the whole branch or its distal 18 inches. Their cluster consisted of a group of 10 trees within a homogenous stand of at least 10 acres (this constituted the sampling universe). From each tree the distal 36 inches of four branches were removed (two from the midcrown and two from the lower crown). Thus, 40 branches from 10 trees constituted the sampling unit. Population levels were expressed as the numbers of budworms per 100 branch tips. (A tip is considered to be any terminal shoot at least one inch long.) Millers (1968a,b,c,d) used the Foltz cluster method of sampling. He retained the 36-inch branch sample for egg mass surveys, but used 18-inch samples for larval and pupal surveys.

POPULATION TREND SURVEYS

At present two systems are widely used for estimating populations in the egg, early larval, late larval, and pupal stages. The system developed by the Wisconsin Department of Natural Resources is also used, with a few modifications, by the Minnesota Department of Natural Resources (1977). The cluster system of Foltz et al., as modified by Millers, is used by the USDA Forest Service.

Population Surveys -Wisconsin System- The Wisconsin Department of Natural Resources has conducted surveys for the jack pine budworm annually at the same locations in northwestern Wisconsin since 1959 (Stewart 1977). Surveys for egg masses, early larvae, late larvae, and pupae, with comments on their development are described below.

Egg Mass Survey-This survey is conducted in August. Initially, the sample branches were taken mainly form the terminals of outer branches. Since such terminals consist mainly of new growth on which female moths rarley lay eggs, many egg masses were missed. (Windy weather during the period of oviposition forces females to remain closer to the trunk of the tree. As a result, more eggs are deposited on the inner branches closer to the trunk.) Since 1967, sample branches have been collected closer to the trunk of the tree. Such branches appear to give a better estimate of the population for the following year. The survey is presently conducted in the following manner:

Two 15-branches (15 inches of needle-bearing surface) are collected from each of three trees at each sample location. These branches are taken at midcrown with a pole pruner, and an attempt is made to obtain branches from the inner part of the crown near the trunk. The branches are fastened together, placed in burlap bags, labeled by plots, and examined in a laboratory under black light (Jennings 1968) for egg masses. Egg masses are placed in vials; after eclosion is complete, the egg masses are examined to determine the approximate percentage of parasitism.

Three egg masses/plot 0.5 egg masses/15 inches of needle-bearing branch surface indicates the potential for damaging defoliation. Areas having more than three egg masses per plot may suffer moderate to severe defoliation the following year.

Early Larval Survey-This survey is probably the most important for detecting the presence of potentially destructive populations. Most larvae emerge from hibernacula about the same time each year, usually between May 24 and June 7. Although second instar larvae are extremely small, they are quite active and are readily seen. Thirty vegetative buds (shoots) and male cones are examined at each plot. These shoots and cones are taken from a minimum of five trees at each location from branches that can be reached from the ground. An effort is made to select approximately 15 male cone clusters and 15 shoots at each plot. When male cones are scarce the sample consists mostly of shoots. Infested cones and shoots are counted, rather than individual larvae. Counting infested shoots and cones instead of the total number of larvae takes 40 percent less time with no loss of accuracy (Clancy et al. 1980). When 20 or 30 shoots are infested the predicted larval population will be 25 per 30 shoots. This population is sufficient to cause moderate to heavy defoliation when the larvae reach the late larval stage.

Late Larval Stage-This survey is conducted in June when most larvae are in their fifth or sixth instar. Two 15-inch branches (15 inches of needle-bearing surface) are collected from each of three trees at each plot. Branch samples are removed from the midcrown with a pole pruner to which a basket is attached. Three larvae/15-inch branch indicates a high population.

Pupal Survey-This survey is conducted in July when most budworms are in the pupal stage. Some adults may have emerged, but the empty pupal cases are collected and counted as emerged adults. The time to collect pupae from lower branches and understory trees is measured. Unless 5 pupae are found in 5 minutes, a collection is terminated. If 5 pupae are found in 5 minutes or less, the time to collect 25 pupae is determine. As they are collected, the pupae are placed in individual gelatin capsules and held in the laboratory until emergence is completed. The number of emerging adults is an indicator of the population potential for the following year. Emergence of parasites indicates the numbers and species of pupal parasites attacking the budworm.

If 25 pupae are collected in less than 15 minutes, a high population may be expected the following year. Although the pupal survey is not considered a good predictor in itself, it can be useful if correlated with other surveys. For example, a low early larval population followed by higher fifth and sixth instar populations, subsequently followed by a high pupal population, indicates a buildup to potentially damaging levels.

Defoliation Surveys-Although no separate surveys are conducted to evaluate defoliation, the current year's defoliation is estimated during the egg mass survey, and a second defoliation estimate is made during the early larval survey the following spring. Defoliation is visually categorized as none, light, medium, heavy, or severe for a stand.

Forms for recording data for population trend surveys are included in Tables 4-7 of the Appendix. Table 1 compares the population levels of the jack pine budworm in the egg, early larval, late larval, and pupal stages that may be expected to produce moderate to severe defoliation as determined by the Wisconsin System and the Cluster System.

Population Surveys- Cluster Sampling- Millers (1968a, b. c, d) modified the Cluster Unit Sampling System developed by Foltz et al. (1968) for conducting surveys in the Lake States.

Four branches, two from the midcrown and two from the lower crown, are removed from each of 10 trees within a homogeneous stand of at least 10 acres. Thus, 40 branches constitute the sample for each cluster. These branch samples should be taken from dominant and codominant trees. For larval and pupal surveys, 18-inch branch samples are used (Fig. 1); 36-inch branches are used for the egg mass survey. The longer branches are considered more reliable for the egg mass survey because they provide more adequately for variations in oviposition sites due to weather conditions.

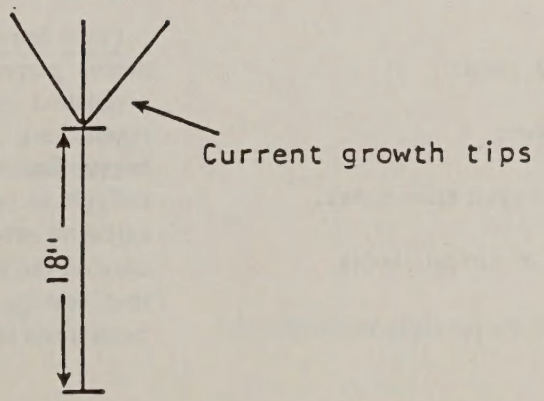

Figure 1. Measurement of 18-inch branch sample for larval and pupal surveys in the cluster system.

Larval and pupal populations are expressed in terms of the number of budworms per 100 tips, (a "tip" is a new growth shoot one inch or longer or a staminate flower bud).

Millers (1968a, b, c, d) recommends that 3 clusters be utilized to evaluate jack pine stands representative of an area. An area of 10,000 to 100,000 acres can be adequately sampled if the clusters are placed in representative stands. If individual areas of jack pine type are separated from one another, much smaller areas should be sampled by 3 clusters. In larger areas 5 to 6 clusters might be necessary if stands are not uniform. Areas should be defined precisely and conclusions limited to the areas sampled. Data from large areas should not be combined. Averaging is not a good idea. It cannot be overemphasized that the perimeter of the survey area must be clearly defined.

In general, an area sampled should be a section or larger. The cluster method is reliable for detecting trends when populations are sampled annually.

The following surveys should be conducted annually on permanent sample clusters to evaluate budworm populations and defoliation:

1. Early larval survey-when most larvae are in the second or third instars and are usually found in the male cones.

2. Late larval survey-when at least 50 percent of the larvae are in the fourth or later instars.

3. Pupal survey-when at least 80 percent of the larvae have pupated.

4. Egg mass survey-when the moth flights are completed.

For the larval and pupal surveys, the bagged samples from each tree are delivered to a counting station where the following information is recorded:

1. Number of shoots.

2. Number of larvae or pupae.

3. Number of male cones.

4. Number of larvae in each male cones.

5. Percent defoliation of current shoots.

6. Percent defoliation of the previous year's growth.

For the egg mass survey, the samples are processed in the field. The egg masses are counted and stored in vials; the number of tips (new shoots) on the branches are recorded, and the degree of egg parasitism is determined.

The population levels for each life stage are expressed as the number of insects/100 tips. The degree of defoliation also is determined for individual shoots and for each stand sampled. Detailed instructions for establishing plots, collecting and handling samples, estimating defoliation, etc., are found in Millers (1968a, b, c, d) and Dixon (1980).

PREDICTING DEFOLIATION FROM CLUSTER POPULATION SURVEY RESULTS

Egg Mass Survey-Egg mass surveys may be useful in predicting rapid increases in populations before defoliation causes the browning of needles (Millers 1979)2/. If the browning of stands is detected, populations are high and probably building to outbreak. The presence of one egg mass/100 tips indicates a potential for browining or visible defoliation. A population of four egg masses/100 tips is equivalent to one egg mass per 18-inch branch. Such an egg population could potentially yield two larvae/tip. Even if a 50-80 percent reduction in population takes place, the potential for severe defoliation is present.

Early Larval Survey-For the early larval survey, a population of 40 or more larvae/100 tips can potentially produce heavy defoliation. In one case a population of 27 larvae/100 tips produced visible defoliation and browning of a stand.

Late Larval Survey-A population of 12 larvae/100 tips (=3 larvae/18-inch branch) can be expected to produce 50 percent defoliation (or more) of the current year's foliage. Browning will also be visible. A population of 5-6 larvae/18-inch branch can be expected to produce 75 percent defoliation.

Pupal Survey-For pupal counts to be useful for predictive purposes, it must be determined whether the population is increasing or decreasing. In declining populations, for example, parasitism will usually be heavy. Because the pupal period is short, it may be difficult to collect an adequate number of samples in extensive areas. This survey does, however, give good data on the level of parasitism. The number of adults that emerge may also be a good indicator of the population potential for the following year.

2/Millers, I., Personal Communication.

Table 1 compares the population levels for the Cluster System and the Wisconsin System at which moderate to heavy defoliation may be anticipated.

CONTROL DECISION SURVEYS

When population monitoring indicates potentially damaging budworm populations, additional surveys are often conducted to make the final decision on whether to apply chemical suppression. One such survey has been conducted in Wisconsin and is described here.

These surveys are usually carried out in mid-June when most larvae are in the fourth or fifth instars and just prior to the time when chemicals are to be applied. (If Bacillus thuringensis is used, sprays should be applied earlier when the larvae are in the third or fourth instar.) At predesigned locations, one 15-inch branch (15 inches of needle bearing surface) is removed from the midcrown of at least 5 different trees with pole pruners. (The stands where collections are made have already been evaluated and designated for control if high populations persist.) A basket is attached to the pole pruner to catch the larvae that spin down readily when disturbed. For each plot the average number of larvae per 15-inch branch is determined. An average population of 3 larvae per 15-inch branch is considered sufficient to cause serious enough defoliation to warrant a control operation.

TABLE 1. Population levels of the jack pine budworm in the egg, early larval, late larval, and pupal stages that can be expected to produce moderate to severe defoliation.

SURVEY	WISCONSIN SYSTEM	CLUSTER SYSTEM
Egg Mass Survey	3 egg masses/plot=0.5 egg masses/15" branch	1 egg mass/36" branch (=4 egg masses/100 tips-potentially severe defoliation 1 egg mass/100 tips-partial browning (visible defoliation)
Early Larval Survey	20 of 30 infested shoots (=25 larvae/30 shoots)	40 larvae/100 tips=potentially heavy defoliation (27 larvae/100 tips in one case give browning (visible defoliation)
Late Larval Survey	3 larvae/15" branch-considered a high population	12 larvae/100 tips 3 larvae/18" branch-can expect 50% defoliation. 5-6 larvae/18" branch-may expect 75% defoliation
Pupal Survey	If 25 pupae are collected in less than 15 minutes-a high population can be expected the following year.	----------

Occasionally it becomes necessary to conduct these decision surveys on an emergency basis. Millers (1979) makes the following recommendations for emergency larval surveys: On a square mile area, forty 18-inch branches should be collected; such samples should be taken from at least 3 different groups of trees. If an unfamiliar area, samples might be taken from 3 to 10 different groups of trees, especially if the infestation is marginal and it is difficult to make a decision. If 4 or more larvae/18-inch branch are present, treatment would be recommended.

DAMAGE APPRAISALS

Defoliation Surveys-One of the most useful techniques for estimating the severity of defoliation is that of Benjamin (1956). This technique was developed to survey large areas rapidly. The instructions for this appraisal survey are taken from Benjamin's publication.

Appraisal Survey-The seriousness of known jack pine budworm infestations in Michigan and Wisconsin is evaluated after defoliation is completed, but before the damaged (clipped) foliage has fallen from the trees. The pupose is to rapidly evaluate an infestation over a large area in minimum time. No attempt is made to collect information about stand composition or site quality.

A series of temporary roadside observation stations is established at intervals of approximately one mile along the major transportation routes throughout the infestation area. The severity of budworm defoliation is estimated at or beyond 200 feet from the road right-of-way. Defoliation is classified as:

1. None (N)-No budworm defoliation evident on trees or reproduction. Crowns of canopy green. No cast pupal skins or trees or reproduction.

2. Light (L)-No budworm defoliation evident, or barely evident, on trees. Crowns of canopy green. Budworm defoliation evident on understory reproduction. Leaders and laterals of understory trees not webbed together. Cast pupal skins present on trees or reproduction.

3. Medium (M)-Budworm defoliation evident on trees. Crowns of canopy predominantly green, but with brownish to reddish background. Defoliation of understory reproduction evident. Leaders and laterals of understory trees webbed together. Cast pupal skins present on trees and understory reproduction.

4. Heavy (H)-Budworm defoliation on trees evident to complete. Crowns of canopy predominantly reddish brown. Defoliation of understory reproduction severe to complete. Leaders and laterals of understory trees webbed together. Cast pupal skins present on trees and understory reproduction.

A survey form (Table 2) is used to record the necessary data at each observation station. The stations are numbered consecutively and the distance from a landmark noted. Each station is located by township (T), range (R), and section (S); and if possible, by quarter section (Q).

The degree of overstory and understory defoliation should be estimated, and the presence of lateral-terminal (L-T) webbing and cast pupal skins noted. The general severity of infestation should also be noted. Any other observations on stand conditions, etc., can be made in the space provided for remarks at the bottom of the form.

A narrative report, summarizing the findings of the survey should include the methods employed, a map indicating categories of defoliation severity by acreages, and general conclusions and recommendaitons.

Kulman et al. (1963) devised a defoliation classification that considers the fact that the budworm feeds on new growth before attacking the old foliage. Individual trees are closely examined with binoculars and with the unaided eye, and then placed in defoliation classes (Table 3, taken from Kulman et. al. (1963).

For new growth, the defoliation percentages listed refer to the number of needles showing damage, not necessarily the number of needles destroyed or consumed. In Minnesota (MN Dep. Nat. Resor. 1977) a modified form of this system has been used in making a defolition surveys.

TABLE 2. Data Sheet for JACK PINE BUDWORM-DEFOLIATION APPRAISAL SURVEY (Benjamin, 1956)

Station Number	Mileage from Landmark	Location				Overstory defoliation				Understory defoliation					Cast pupal skins		Severity of infestation			
		T	R	S	Q	N	L	M	H	N	L	M	H	L-T web-bing	Under-story	Over-story	N	L	M	H

Remarks:

TABLE 3. Classification of current year's defoliation of jack pine by the jack pine budworm.

General defoliation class	Defoliation class designation.	Percent of new growth showing feeding damage	Percent of old needles consumed
0 to very light	1	0-25	0
Light	2	26-75	0
Medium	3	76-100	0-25
Heavy	4	100	26-75
Very heavy	5[1]/	100	76-100

1/A "t" after some "5" designations indicates that defoliation is concentrated in the top of the tree.

Millers (1968c) used a system in which defoliation was estimated on branch samples collected during the larval and pupal surveys. For each branch sample defoliation was estimated for current growth (new growth), 1-year old needles (old growth), and needles older than 1 year (old growth).

Defoliation was catergorized as:

0-NONE; defoliation 0-5% (0)
1-LIGHT; defoliation 6-40% (1/4)
2-MODERATE; defoliation 41-60% (2/4)
3-SEVERE; defoliation 61-94% (3/4)
4-COMPLETE; defoliation 95-100% (4/4)

In addition to branch defoliation estimates, whole stand estimates were made in 10 percent classes by determining defoliation of the average trees in the stand.

Aerial Surveys-Aerial surveys are efficient for quickly determining the severity and extent of defoliaiton in an outbreak area. Benjamin (1956) described an aerial survey method for evaluating jack pine budworm defoliation. His method, with a severe category added and a redefinition of the medium category, is described below.

Jack pine budworm infestations can be evaluated from the air by examining infestations along predetermined flight lines at uniform intervals from 1 to 12 miles. Random or meandering flights along the boundaries of known infestations can also be used.

The following factors should be considered when an aerial survey is to be conducted:

1. Training-Areas of known defoliation intensity should be located on the ground and flown over to familiarize observers with different defoliation classes.

2. Criteria for defoliation classes-
   a. None-light-No defoliation evident. Crowns normal green.
   b. Medium-Defoliation evident. Crowns predominantly green with brownish background, or mottling of an area-brown scattered among green.
   c. Heavy-Defoliation evident. Crowns predominantly reddish brown.
   d. Severe-Defoliation evident. Little foliage left on trees. Trees appear gray, indicating probable top kill and mortality.

3. Observations-A single-engine, high-wing airplane such as a Cessna 170-B3/ or Cessna 180 gives satisfactory performance and provides adequate room for two servers. The flight lines should be 1-3 miles apart along north-south or east-west lines. The altitude should be 1000-1500 feet. The methods used by Munson and Haynes (1981) and by Waters et al. (1958) for spruce budworm can also be adapted to jack pine budworm aerial surveys.

4. Mapping-County, highway, cover type or aerial navigation maps can be used. If available, a scale of ½ inch or 1 inch per mile is preferable. The general location of defoliation classes can be sketched using the criteria specified in number 2 above.

5. Ground Verification-Aerial observations should be checked on the ground. Other insects, drought, or disease agents can also cause browning of needles.

Flights along township lines at 3,000 feet will detect moderate (medium) to severe defoliation, but will not reveal light defoliaiton. If a survey is to be made for salvage purposes, it is probably to make the flight after the brown needles have dropped. Gray trees are being looked for in salvage flights.

3/Mention of commercial products is for convenience only and does not imply endorsement by USDA and its cooperators.

Impact Surveys-Benjamin (1956) described a survey for evaluating tree mortality and top killing under the title of "Timber Drain Surveys". The survey should be conducted after the budworm feeding period is over and defoliaiton is complete, usually from mid-August to early September. The following steps are generally followed:

1. The total area of infestation is determined from survey maps or aerial surveys. The total area for each defoliation category (none, light, medium, or heavy) is determined.

2. The number of plots necessary to adequately sample the area is determined from the Lake States Forest Insect Survey Committee Intensity of Sampling Statement (1956). The number of plots required is based upon stand density and uniformity, stand value, area to be sampled, and standard of accuracy required.

3. The plots are located according to the following procedures:

a. The mileage from a definite landmark such as a river or side road is recorded. If walking or cruising, the distance from a landmark is estimated. When the survey is conducted by road, plots should be located approximately 5 chains from the road right-of-way.

b. The plots should be 1/5 acre in size. Plots are examined by sectors using two plastic ropes, each 52.7 feet long, attached to a center tree. The diameter is measured with a diameter tape or cruiser's stick, and the number of logs per tree is estimated or determined by cruiser's stick. Reproduction is determined by actual tally.

4. Trees are tallied by species and diameter class as follows; reproduction, 2-inch saplings, 4-inch saplings, 6-inch and over merchantable poles. Health class should be recorded as: 1) living; 2) dead, budworm killed; and c) dead (suppresseed) budworm killed.

EMERGENCY CONTROL EVALUATIONS (PRE-AND POST-SPRAY EVALUATIONS)

Chemical of microbial sprays to reduce budworm larval populations are usually applied when the budworm is in the fourth of fifth larval instar. Microbials, such as Bacillus thuringensis, are usually applied earlier when the larvae are in the third or fourth instar. To evaluate the effectiveness of control, budworm larval populations are estimated before and after the spraying operation in both treated and untreated (check) areas. Post-spray population estimates are commonly conducted 24, 48, and 72 hours after treatment.

Since populations will probably decline somewhat in both treated and untreated (check) areas whether or not treatment is applied, population reductions attributable to the control effort are often calculated using the Abbott correction:

$$\% \text{ reduction due to treatment-1} = \frac{(CB \times TA)}{(CA \times TB)} \times 100$$

where:

CB-=check, total larvae before treatment
CA= check, total larvae after treatment
TB =treated area total larvae before treatment
TA = treated area total larvae after treatment

Either 15-inch branch sampling or cluster sampling could be used in making pre- and post-spray evaluations. The "control decision survey" described earlier could serve as a pre-spray survey (Table 8, Appendix). Millers (1979) makes comments below about pre- and post-spray surveys.

For pre-spray surveys, a minimum sample of 200 larvae is suggested; 500 to 1,000 larvae would be better. For post-spray surveys, it may be desirable to double the number of samples taken. For example, if 100 trees were sampled on the pre-spray survey, 200 trees might be sampled on the post-spray survey; or two branches per tree might be taken on the post-spray survey when one branch is taken on the pre-spray survey. Doubling the number of post-spray samples tends to reduce variability and to avoid zeros in the sample counts. (However, time and labor cost will likely influence whether or not the number of post-spray samples is doubled).

If the cluster system is used, a cluster should not cover more than one spray swath. Then, for example, if 1 to 10 clusters is missed during a spray operation, the evaluator knows that 10 percent of the area was not adequately covered. Knowledge of coverage is essential in determining the effectiveness of any control operation.

METHODS FOR PROCESSING SAMPLES RAPIDLY

Time is often a limiting factor in survey work. The methods described briefly below can be invaluable when

rapid processing of samples is necessary.

DeBoo et al. (1973) and Martineau and Benoit (1973) developed a method for the rapid processing of large numbers of branch samples for estimating population trends of the spruce budworm and jack pine budworm. The technique utilizes a portable table and funnel or a portable drum. Branch samples are beaten over the funnel or drum and insects that fall are collected and counted. The system allows processing of branch samples in the field, and is approximately four times as fast as the counting mill with attendant cost savings. The technique should be readily adaptable to either the 15-inch branch or the cluster sampling method.

Counting eggs in jack pine budworm egg masses is tedious and time consuming. Individual eggs are difficult to distinguish, espically after larval eclosion. Jennings and Addy (1968) developed a staining technique for rapidly counting eggs. More recently, Batzer and Jennings (1980) developed regression equations using egg mass length for estimating the number of eggs in a mass. Jennings (1968) has also described the use of black light for locating jack pine budworm egg masses.

REFERENCES

Batzer, H.O., and D.T. Jennings. 1980. Numerica. anaylysis of a jack pine budworm outbreak in dense jack pine. Eviron. Entomol: 9:514-424.

Benjamin, D.M. 1956. Jack pine budworm surveys, Coop. Econ. Insect Rept. P1. Pest Control Branch A.R.S., Argic. 6:705-709.

Benjamin, D.M. 1965. Evaluation of outbreak populations of the jack pine budworm, Choristoneura pinus Freeman (Lepidoptera). Proc. XII Int. Cong. Entomol., London, 1964:697.

Clancy, K.M., Benjamin, R.L. Giese, and R.B. Stewart. 1980 The relationship between jack pine budworm early larval density to frequency of infested vegetative and staminate flower buds. Entomol. News: 91:75-77.

DeBoo, R.F., L.M. Campbell, and A.G. Copeman. 1973. A sampling technique for estimating numerical trends in larval populations of insect defoliators. I. Development and experimental evaluation of the technique. Phytoprotection 54:9-22.

Dixon, J.C. 1961. The biology and ecology of the jack pine budworm in Wisconsin with special reference to insect parasites. Univ. of Wisconsin-Madison, Ph. D. Thesis.

Dixon, J.C. 1980. Report on project to develop a survey manual for jack pine budworm. USDA For. Serv. S&PF. NE Area (unpublished) 64 pp.

Foltz, J.L., F.B. Knight, D.C. Allen, and W.J. Mattson. 1968. A technique for sampling populations of the jack pine budworm. For. Sci. 14:277-281.

Freeman, T.N. 1953. The spruce budworm, Choristoneura fumiferana (Clem.), and an allied new species on pine (Lepidoptera: Tortricidae). Canad. Entomol. 85:121-127.

Freeman, T.N. 1967. On coniferophagous species of Choristoneura (Lepidoptera: Tortricidae) in North America. I. Some new forms of Choristoneura allied to C. fumiferana. Canad. Entomol. 99:449-455.

Jennings, D.T. 1968. Using black light to find jack pine budworm egg masses. North Central For. Exp. Sta. Research Note NC-56.

Jennings, D.T., and N.D. Addy. 1968. A staining technique for jakc pine budworm egg masses. J. Econ. Entomol. 61:1766.

Kulman, H.M., and A.C. Hodson. 1962. A sampling unit for the jack pine budworm, Choristoneura pinus. J. Econ. Entomol. 55:801-802.

Kulman, H.M., A.C. Hodson, and D.P. Duncan. 1963. Distribution and effects of jack pine budworm defoliation. Forest Sci. 9:146-157.

Lake States Forest Insect Survey Committee. 1956. Intensity of sampling statement. Coop. Econ. Insect Rept. P1. Pest Control Branch A.R.S., USDA 6:675.

Lejeune, R.R., and W.F. Black. 1950. Populations of larvae of the jack pine budworm. Forestry Chron. 26:152-156.

Martineau, R., and P.B. Benoit. 1973. A sample technique for estimating numerical trends in larval populations of insect defoliators on conifers II. Modification and operational use of the technique for extensive sampling of spruce budworm population in Quebec. Phyto Protection 54:23-31.

Millers, I. 1968a. Survey for jack pine budworm population trends (Egg-mass cluster survey). Ditto. USDA Forest Service R-9 5230.

Millers, I. 1968b. Field instructions for jack pine budworm larval survey. Ditto. USDA Forest Service R-9 5230.

Millers, I. 1968c. Field instructions for examination of jack pine branch samples for jack pine budworm larvae and pupae. Ditto. USDA Forest Service R-9 5230.

Millers, I. 1968d. Evaluation plan for jack pine budworm larval populations in the Lake States. Ditto. USDA Forest Service R-9 5230.

Minn. Dep. Nat. Resour. 1977. Forest pest report.

Munson, A.S., and E.M. Haynes. 1981. Aerial survey of spruce budworm damage on the Nicolet National Forest, 1981. USDA For. Serv. S&PF NE Area (unpublished) 5 pp.

Stewart, R.B. 1977. Surveys conducted in northwestern Wisconsin for the jack pine budworm, Choristoneura pinus Freeman. Central International Forest Insect and Disease Conference, Duluth, MN.

Waters, W.E., R.C. Heller, and J.L. Bean. 1958. Aerial appraisal of damage by the spruce budworm. J. For. 56:269-276.

APPENDIX

DATA SHEETS

POPULATION TREND SURVEYS DEVELOPED

BY THE WISCONSIN DNR FOR THE

WISCONSIN SYSTEM

TABLE 4.

JACK PINE BUDWORM
Egg Mass Survey
Two 15" Branches from 3 Trees

COUNTY _____

Date	Location (Twp., Range, Sec., Forty)	Total Egg Masses	Defoliation (None, light, medium, heavy, severe)	Remarks

TABLE 5.

JACK PINE BUDWORM
Early Larval Survey
Counts Based on Examination of 30 New Shoots
or Staminate Flowers (Male Cones)

COUNTY _____

Date	Location (Twp., Range, Sec., Forty)	No. Larvae	Larval Instar	Staminate Flowering (Male Cones) (None, Scarce, Common, Heavy)	Previous Defoliation (None, Light, Medium, Heavy, Severe)	Timber Type Size & Stocking	Remarks

TABLE 6.

JACK PINE BUDWORM
Late Larval Survey
Two 15" branches from 3 trees

COUNTY _____

Date	Location (Twp., Range, Sec., Forty)	Tree #1	Tree #2	Tree #3	Total (Larvae & Pupae)	Average per 15" br.	Remarks

TABLE 7.

JACK PINE BUDWORM

Pupal Survey

COUNTY _____

Date	Location (Twp., Range, Sec., Forty)	No. Pupae	Time	Moths	Parasitized	Not Emerged	Remarks

TABLE 8.

JACK PINE BUDWORM PRE-SPRAY SURVEY

LOCATION	No. of Budworm Per 15" Surface 1 2 3 4 5 6 7 8 9 10	TOTAL BW LARVAE TEN SAMPLES	AVE. NO. of BW LARVAE/15"	DEFOLIATION	RECOMMEND